

A SYSTEM AND METHOD FOR HANDLING A BOIL OFF GAS

TECHNICAL FIELD

[001] The present disclosure relates broadly, but not exclusively, to systems and methods for handling a boil off gas (BOG) from a cryogenic liquid storage tank.

BACKGROUND OF THE DISCLOSURE

[002] Typically, a cryogenic liquid, such as liquefied natural gas (LNG), has a negative boiling point. Carriers equipped with cryogenic liquid storage tanks are typically used to transport cryogenic liquids. During voyage, the cryogenic liquids in the storage tanks may continuously vaporize into boil off gas (BOG) due to heat ingress from the surroundings into the storage tanks. Factors such as tank loading conditions, ambient temperature and vessel movement can affect a boil off rate of the cryogenic liquids in the storage tanks. An increase in the volume of BOG in the storage tanks can result in a rise in the storage tanks pressure. As such, the BOG in the storage tanks may need to be removed to modulate the storage tanks pressure so that it is within operational limits.

[003] Typically, the BOG in the storage tanks may be vented to the atmosphere when an emergency occurs during voyage or when the carrier is not moving, e.g. a vessel at anchorage, in order to modulate the storage tanks pressure. However, this can pose a safety hazard and may not be permitted due to regulations, especially when the carrier is not moving, e.g. a vessel in port. Another existing solution involves simply burning off the BOG. Thus, energy that could have been tapped from the vented BOG may be wasted.

[004] A need therefore exists to provide a system and method for handling BOG in cryogenic liquid storage tanks that seek to address at least some of the above problems. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[005] According to a first aspect, there is provided a system for handling a boil off gas (BOG) from a cryogenic liquid storage tank, the system comprising: a heater in fluid communication with the cryogenic liquid storage tank, the heater configured to receive and heat the BOG; and a compressor disposed downstream of the heater, the compressor configured to receive and compress the heated BOG to a first pre-determined pressure.

[006] The compressor may be a multi-stage compressor.

[007] The compressed BOG at the first pre-determined pressure may be supplied to a main engine.

[008] The system may further comprise a gas supply line connecting the heater to one or more boilers, wherein the gas supply line is configured to supply the heated BOG to the one or more boilers.

[009] The system may further comprise one or more flow directing devices disposed downstream of the heater, the one or more flow directing devices configured to selectively direct the heated BOG to either the compressor or the one or more boilers.

[0010] The system may further comprise a decompression system disposed downstream of the compressor, the decompression system configured to receive and decompress the compressed BOG to a second pre-determined pressure lower than the first pre-determined pressure.

[0011] The decompressed BOG may be supplied to a generator set and/or the one or more boilers.

[0012] According to a second aspect, there is provided a method for handling a boil off gas (BOG) from a cryogenic liquid storage tank, comprising: releasing a flow of BOG from the cryogenic liquid storage tank if a pressure of the cryogenic liquid storage tank reaches an upper threshold; heating the released flow of BOG; directing, based on a first condition, the heated BOG to a compressor; compressing the heated BOG to a first pre-determined pressure; and stopping the flow of BOG from the cryogenic liquid storage tank if the pressure of the cryogenic liquid storage tank reaches a lower threshold.

[0013] The first condition may comprise a main engine running and/or a generator set running.

[0014] The method may further comprise supplying, if the main engine is running, the compressed BOG to the main engine.

[0015] The method may further comprise: if the main engine is not running, directing the compressed BOG to a decompression system disposed downstream of the compressor; decompressing, by the decompression system, the compressed BOG to a second pre-determined pressure lower than the first pre-determined pressure; and supplying the decompressed BOG to the generator set.

[0016] The method may further comprise supplying the decompressed BOG to one or more boilers.

[0017] Compressing the heated BOG to the first predetermined pressure may comprise compressing the heated BOG through a plurality of stages.

[0018] The method may further comprise, after heating the released flow of BOG, directing, based on a second condition, the heated BOG to one or more boilers.

[0019] The second condition may comprise the main engine not running and the generator set not running.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Embodiments and implementations are provided by way of example only, and will be better understood and readily apparent to one of ordinary skill in the art from the following written description, read in conjunction with the drawings, in which:

[0021] Figure 1 is a schematic representation of a system for handling a boil off gas (BOG) from a cryogenic liquid storage tank, according to an example embodiment.

[0022] Figure 2 is a flowchart illustrating a method for handling a BOG from a cryogenic liquid storage tank, according to an example embodiment.

[0023] Figure 3 is a graph showing an example of a cryogenic liquid storage tank pressure over a period of time.

[0024] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale.

DETAILED DESCRIPTION

[0025] Embodiments will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[0026] Embodiments of the invention provide a system for handling a boil off gas (BOG) from a cryogenic liquid storage tank that may be safer and more energy efficient. The cryogenic liquid storage tank(s) may be installed on a carrier for transporting for example, but not limited to crude oil, chemical or containerized goods. Non-limiting examples of cryogenic liquids that may be stored in the cryogenic liquid storage tank(s) include liquefied natural gas (LNG) and liquid hydrogen. Example carriers include, but are not limited to, ocean-going vessels, or rail transporters. As mentioned above, during voyage, the cryogenic liquids in the storage tanks may continuously vaporize into BOG due to heat ingress from the surroundings into the storage tanks. An increase in the volume of BOG in the storage tanks can result in a rise in the storage tanks pressure. As such, the BOG in the storage tanks may need to be removed to modulate the storage tanks pressure so that it is within operational limits.

[0027] Figure 1 is a schematic representation of a system 100 for handling a boil off gas (BOG) 102 from a cryogenic liquid storage tank (not shown), according to an example embodiment. The system 100 comprises a heater 104 in fluid communication with the cryogenic liquid storage tank. In other words, the heater 104 may be connected to the cryogenic liquid storage tank with pipeline(s). Flow directing device(s) (not shown), such as valve(s), may be installed in the pipeline(s) to control a flow of the BOG 102 from the cryogenic liquid storage tank to the heater 104. The heater 104 is configured to receive and heat the BOG 102. The BOG 102 may be heated to different temperatures based on a requirement of machine(s) receiving the heated BOG. For example, the machine(s) can be a compressor or boiler(s). The system 100 also comprises a compressor 110

disposed downstream of the heater 104. The compressor 110 is configured to receive and compress the heated BOG to a first pre-determined pressure. The compressed BOG at the first pre-determined pressure may be supplied to a machine such as a main engine 106. Accordingly, the first pre-determined pressure can be based on a requirement of the machine. As a non-limiting example, the first pre-determined pressure can be 315 bar if the compressed BOG is supplied to the main engine 106. In some implementations, the compressed BOG can be combined with a high pressure gas from a pump 108 before being supplied to the main engine 106.

[0028] During voyage and under various sailing conditions, tank loading conditions and environmental conditions, the system 100 can allow the BOG to be used as part of a fuel supply to the main engine 106 when a need for the BOG by auxiliary machines such as a generator set is relatively low. In this manner, the BOG need not be burnt in the boilers or in cases of emergency, vented to the atmosphere. Hence, environmental safety and energy efficiency can be enhanced.

[0029] In some embodiments, the compressor 110 may be a multi-stage compressor. The multi-stage compressor 110 can compress the heated BOG from the heater 104 to a relatively higher pressure, such as 315 bar. It will be appreciated that if the machine receiving the compressed BOG does not require such a high pressure BOG, a single-stage compressor may be used instead. Also, the number of stages can be varied depending on the desired output pressure.

[0030] The system 100 may further comprise a gas supply line 112 connecting the heater 104 directly to one or more boilers. The gas supply line 112 may be configured to supply the heated BOG to the one or more boilers. As a non-limiting example, the one or more boilers can be an auxiliary boiler 114 and/or composite boiler 116.

[0031] The system 100 may further comprise one or more flow directing devices 118 disposed downstream of the heater 104. The one or more flow directing devices 118 may be configured to selectively direct the heated BOG to either the compressor or the one or more boilers. The one or more flow directing devices 118 can be valve(s) installed in pipeline(s) downstream of the heater 104 and before branching into separate pipelines that connect the heater 104 to the compressor and the one or more boilers, respectively. The one or more flow directing devices 118 can also be valve(s) installed in the gas supply line 112. Furthermore, the one or more flow directing devices 118 can be valve(s)

installed in the pipeline connecting the heater 104 to the compressor. The one or more flow directing devices 118 may be operated manually or via an automated system.

[0032] The system 100 may further comprise a decompression system 120 disposed downstream of the compressor 110. The decompression system 120 may be configured to receive and decompress the compressed BOG to a second pre-determined pressure lower than the first pre-determined pressure.

[0033] The decompressed BOG may be supplied to machine(s) such as a generator set 122 and/or the one or more boilers. Accordingly, the second pre-determined pressure can be based on a requirement of said machine(s). As a non-limiting example, the second pre-determined pressure can be 10 bar. In some implementations, the decompressed BOG can be combined with a low pressure gas from a tank 124 before being supplied to the generator set 122 and/or the one or more boilers.

[0034] According to one embodiment, the decompression system 120 may comprise a first set of pressure reducing valves 126, a heater 128 and a second set of pressure reducing valves 130. A compressed BOG after a last stage of the multi-stage compressor 110 and before passing through a cooler 132 can be supplied to the first set of pressure reducing valves 126 of the decompression system 120. As a non-limiting example, the first set of pressure reducing valves 126 may reduce the pressure of the compressed BOG from 315 bar to 200 bar. As the pressure of the compressed BOG decreases, the BOG may expand and cool down. The cooled down BOG may be supplied to the heater 128 to be heated up. The heated BOG may be supplied to the second set of pressure reducing valves 130. As a non-limiting example, the second set of pressure reducing valves 130 may reduce the pressure of the heated BOG from 200 bar to 10 bar. By reducing the pressure of the compressed BOG in multiple stages as described above, a usage life of the first and second sets of pressure reducing valves 126, 130 can be increased. It will be appreciated that the decompression system 120 can also comprise any number of sets of pressure reducing valves and any number of heaters.

[0035] In some implementations, the compressor 110 disposed downstream of the heater 104 may pump a constant volume of gas. In order to overcome this limitation, a temperature of the BOG 102 from the cryogenic liquid storage tank can be varied using the heater 104. By varying the temperature of the BOG, mass flow of the BOG can be varied due to a change in density of the BOG while a volume of the BOG remains constant. The BOG can then be supplied to the compressor at a mass flow below a design mass flow of the compressor when running at minimum speed.

[0036] In other words, the system 100 can adapt to different conditions or different kinds of usage situations.

[0037] Figure 2 is a flowchart 200 illustrating a method for handling a BOG from a cryogenic liquid storage tank, according to an example embodiment. At step 202, a flow of BOG from the cryogenic liquid storage tank is released if a pressure of the cryogenic liquid storage tank reaches an upper threshold. In this manner, the pressure of the cryogenic liquid storage tank may not exceed its upper operational limit. At step 204, the released flow of BOG is heated. At step 206, the heated BOG is directed to a compressor based on a first condition. At step 208, the heated BOG is compressed to a first pre-determined pressure. At step 210, the flow of BOG from the cryogenic liquid storage tank is stopped if the pressure of the cryogenic liquid storage tank reaches a lower threshold.

[0038] In some implementations, the first condition may comprise a main engine running and/or a generator set running. The method may further comprise supplying, if the main engine is running, the compressed BOG to the main engine. Accordingly, the first pre-determined pressure can be based on a requirement of the machine. As a non-limiting example, the first pre-determined pressure can be 315 bar if the compressed BOG is supplied to the main engine.

[0039] The method may further comprise directing the compressed BOG to a decompression system disposed downstream of the compressor if the main engine is not running. The method may also comprise decompressing, by the decompression system, the compressed BOG to a second pre-determined pressure lower than the first pre-determined pressure. Further, the method may comprise supplying the decompressed BOG to the generator set.

[0040] According to one embodiment, the method may further comprise supplying the decompressed BOG to one or more boilers. Compressing the heated BOG to the first predetermined pressure may comprise compressing the heated BOG through a plurality of stages.

[0041] The method may further comprise directing the heated BOG to one or more boilers based on a second condition and after heating the released flow of BOG. The second condition may comprise the main engine not running and the generator set not running.

[0042] In other words, the BOG can be handled differently based on different conditions or different kinds of usage situations.

[0043] Figure 3 is a graph 300 showing an example of a cryogenic liquid storage tank pressure over a period of time. As shown in the graph 300, a temperature of an LNG and BOG in the cryogenic liquid storage tank increases over time. Correspondingly, the pressure of the cryogenic liquid storage tank increases. As the pressure of the cryogenic liquid storage tank increases to an upper threshold of the cryogenic liquid storage tank that is close to an upper operational limit, a flow of BOG from the cryogenic liquid storage tank can be released. In other words, the BOG built up in the cryogenic liquid storage tank can be transferred out of the cryogenic liquid storage tank. When the pressure of the cryogenic liquid storage tank drops to a lower threshold of the cryogenic liquid storage tank, the flow of BOG from the cryogenic liquid storage tank is stopped. In other words, the BOG can no longer be transferred out of the cryogenic liquid storage tank. In this manner, pressure in the cryogenic liquid storage tank can be modulated so that it is within operational limits.

[0044] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. For example, the type of compressor may vary depending on the requirements of the machines that the BOG will be supplied to. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A system for handling a boil off gas (BOG) from a cryogenic liquid storage tank, the system comprising:
 - a heater in fluid communication with the cryogenic liquid storage tank, the heater configured to receive and heat the BOG; and
 - a compressor disposed downstream of the heater, the compressor configured to receive and compress the heated BOG to a first pre-determined pressure.
2. The system of claim 1, wherein the compressor is a multi-stage compressor.
3. The system of claim 1 or 2, wherein the compressed BOG at the first pre-determined pressure is supplied to a main engine.
4. The system of any one of the preceding claims, further comprising a gas supply line connecting the heater to one or more boilers, wherein the gas supply line is configured to supply the heated BOG to the one or more boilers.
5. The system of claim 4, further comprising one or more flow directing devices disposed downstream of the heater, the one or more flow directing devices configured to selectively direct the heated BOG to either the compressor or the one or more boilers.
6. The system of claim 4 or 5, further comprising a decompression system disposed downstream of the compressor, the decompression system configured to receive and decompress the compressed BOG to a second pre-determined pressure lower than the first pre-determined pressure.
7. The system of claim 6, wherein the decompressed BOG is supplied to a generator set and/or the one or more boilers.
8. A method for handling a boil off gas (BOG) from a cryogenic liquid storage tank, comprising:
 - releasing a flow of BOG from the cryogenic liquid storage tank if a pressure of the cryogenic liquid storage tank reaches an upper threshold;
 - heating the released flow of BOG;
 - directing, based on a first condition, the heated BOG to a compressor;
 - compressing the heated BOG to a first pre-determined pressure; and

stopping the flow of BOG from the cryogenic liquid storage tank if the pressure of the cryogenic liquid storage tank reaches a lower threshold.

9. The method of any one of claim 8, wherein the first condition comprises a main engine running and/or a generator set running.

10. The method of claim 9, further comprising supplying, if the main engine is running, the compressed BOG to the main engine.

11. The method of claim 9 or 10, further comprising:
if the main engine is not running, directing the compressed BOG to a decompression system disposed downstream of the compressor;
decompressing, by the decompression system, the compressed BOG to a second pre-determined pressure lower than the first pre-determined pressure; and
supplying the decompressed BOG to the generator set.

12. The method of claim 11, further comprising supplying the decompressed BOG to one or more boilers.

13. The method of any one of claims 8 to 12, wherein compressing the heated BOG to the first predetermined pressure comprises compressing the heated BOG through a plurality of stages.

14. The method of claim 8, further comprising, after heating the released flow of BOG, directing, based on a second condition, the heated BOG to one or more boilers.

15. The method of claim 14, wherein the second condition comprises the main engine not running and the generator set not running.